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Messiah College is a Christian college of the liberal and applied arts and sciences. Our mission is to educate men and women toward maturity of intellect, character and Christian faith in preparation for lives of service, leadership and reconciliation in church and society.
No Difference Observed in Sedentary Time per Week between NCAA DIII Distance Runners and Recreationally Active College Students
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Abstract

Sedentary behavior, defined as activities with an energy cost below 1.6 metabolic equivalents (METs), is associated with chronic health risks and mortality even in active individuals. Time spent at sedentary MET levels by Messiah College collegiate distance runners and recreationally active students was documented and analyzed to determine whether competitive athletes accrue more sedentary time than recreationally active students. In this descriptive cross-sectional study, 22 competitive distance runners and 26 recreationally active students wore SenseWear™ armbands (SWA; BodyMedia, Inc.) continuously for seven days of free-living activity. Male (n = 10) and female (n = 12) distance runners were Messiah College track athletes in distance events (800m through 10000m) and who reported running more than 30 miles weekly. The recreationally active group consisted of male (n = 14) and female (n = 12) full-time Messiah College students who reported running at least six but less than 30 miles weekly, or equivalent physical activity and no participation in NCAA intercollegiate sports. The SWA recorded the subjects' total time at sedentary MET levels for seven days. The difference in mean sedentary time for the week between the two groups was analyzed using 2x2 factorial ANOVA for independent samples with standard weighted-means analysis (VassarStats, www.vassarstats.net). No significant difference in mean sedentary time was found between the groups (P = 0.73). NCAA DIII collegiate distance runners do not accrue more time at sedentary MET levels than recreationally active college students. More research is needed to assess the health implications of time spent sedentary by both groups.
No Difference Observed in Sedentary Time per Week between NCAA DIII Distance Runners and Recreationally Active College Students

Recent studies investigating the impact of sedentary behavior on health form a growing body of literature that links lifestyles marked by sedentary behavior to numerous health problems. Sedentary behavior includes activities that require minimal exertion above resting energy expenditure such as lying down, sitting, and screen time (1). Sedentary behavior is associated with greater waist circumference, increased blood insulin and glucose, lower HDL cholesterol, metabolic syndrome, reduced physical and psychosocial health and increased BMI in adolescents, increased cardiovascular disease risk independent from moderate to vigorous physical activity in youth and adults, unfavorable levels of adiposity-associated inflammation, and decreased mental well-being (2-9). According to findings from the ongoing Harvard Alumni Health Study, bouts of moderate to vigorous physical activity (one to two sessions per week) that were interspersed with longer periods of sedentary behavior instead of physical activity most days of the week were less protective from cardiovascular disease risk than more frequent bouts of exercise even if the total energy expenditure from both activity patterns was equivalent (10). A large prospective study of U.S. adults by Patel et al. concluded that time spent sitting was independently associated with total mortality regardless of physical activity level (11). In contrast, some studies have suggested that the interaction between sedentary behavior and cardiometabolic risk factors (pertaining to both heart disease and metabolic diseases such as diabetes) is not completely independent from moderate to vigorous physical activity levels (12-14). However, these studies still acknowledge that sedentary behavior has adverse effects and suggest further investigation of the interaction between sedentary time, physical activity, and disease.

The studies mentioned above focused on screen time-related sedentary behavior by adolescents or sedentary behavior by older adults and individuals with existing diseases rather than sedentary time in healthy young adults or athletes. Few studies have investigated the effects of sedentary behavior on healthy young adults. Analysis by Thyfault and Krogh-Madsen of studies involving reduced ambulatory activity in rats and young, healthy men found that reduced physical activity led to increased central adiposity and insulin resistance (15). When the activity of the healthy young men was reduced from greater than 10,000 steps per day to less than 1,500 steps per day for 14 days with no change in dietary habits, insulin response decreased and central adiposity increased despite significant reduction in body weight. Thyfault and Krogh-Madsen suggested that although the acute response to sedentary behavior cannot be directly linked to development of chronic disease, the acute changes tended in a pathological direction. If the detrimental effects extend to periods shorter than 14 days, even individuals who are otherwise active but engage in extended periods of sedentary behavior may risk acute responses that produce negative cardiometabolic changes.

Sedentary time has not been quantified in the general population and guidelines for sedentary time have not been developed for adults. However, analysis of physical activity behavior in the US implies that sedentary behavior is prevalent. Data obtained from the 2003-2004 National Health and Nutritional Examination Survey (NHANES) suggests that less than 5% of adults meet the latest US Department of Health and Human Services Physical Activity Guidelines for Americans (PAGA) of at least 150 minutes of moderate exercise weekly (16,17). Separate studies conducted by Troiano et al. and Metzger et al. both analyzed seven days of accelerometer data from the 2003-2004 NHANES and found that a large portion of the US
population engages in less physical activity than recommended by the PAGA and related guidelines (18-20). This trend has been verified among the college student population. Dinger and Behrens observed physical activity of free-living college students via accelerometer data and concluded that most of the study's subjects were not meeting recommendations with regard to physical activity bouts of at least 10 consecutive minutes (21). Exercise in sessions of at least 10 minutes are recommended by the American College of Sports Medicine and American Heart Association physical activity recommendations and incorporated into the PAGA (17,19).

As noted earlier, research in the area of sedentary behavior in athletes has been limited. Previous studies have investigated energy efficiency and conservation in amenorrheic female endurance athletes (22-24) but not sedentary time specifically. Sedentary behavior seems to be unexplored entirely for male athletes. Possible contributing factors to this include the assumption that athletes do not engage in significant sedentary behavior and the relatively recent emergence of research on the health risks of sedentary behavior independent of activity level. The premise of this study was that the intense activity required of endurance athletes for competition at the NCAA level may actually increase their risk for engaging in sedentary behavior when not engaged in training activities. The purpose of this study was to determine whether NCAA Division III distance runners compensate for the time and energy required by their training by accumulating more minutes at a sedentary activity level than recreationally active college students. If collegiate distance runners do accrue more sedentary time than their recreationally active peers, changes in training practices may be warranted to avoid the health risks associated with increased levels of sedentary behavior.

**Methods**

**Participants**

The subject population (n = 48) consisted of full-time students at Messiah College (Grantham, PA) who were either NCAA Division III distance runners participating in Messiah College Track and Field (CDR; n = 10 men; n = 12 women) or non-NCAA intercollegiate athlete students who engaged in regular aerobic exercise, typically jogging or running (RAS; n = 14 men; n = 12 women). Eligibility criteria for CDR were participation in NCAA DIII competition and running mileage greater than or equal to 30 miles/week. Eligibility criteria for RAS were non-participation in NCAA athletic competition and physical activity of at least six miles but less than 30 miles per week of walking/running or the equivalent through other aerobic activities such as biking. This standard was based on the PAGA criteria achieving substantial health benefits through moderate activity (17). Both male and female subjects were recruited and no particular ethnic or racial groups were excluded. Subjects with electronic medical implants were excluded due to the risk posed to their health by bioelectric impedance body composition analysis. CDR were recruited informally by word-of-mouth. RAS were recruited both through word-of-mouth and on-campus posters. No compensation was offered for participation. The Messiah College Institutional Review Board approved the study protocol and all participants provided written informed consent.

**Preliminary Procedures**

Subjects completed a questionnaire to screen subjects at health risk due to electronic medical implants. The questionnaire also required subjects to indicate their compliance with pre-measurement protocols, which consisted of avoiding large meals, vigorous exercise, and sleep
for three hours prior to help control error in the body fat percentage measurement. Subjects' height to the nearest quarter inch, weight to the nearest tenth of a pound, and body fat percentage to the tenth of a percent were assessed using a stadiometer and the Tanita BF-682W Scale Plus Body Fat Monitor (Tanita, Corp. of America, Inc., Arlington Heights, IL). Subjects received a BodyMedia SenseWear™ Pro3 armband (SWA; BodyMedia Inc, Pittsburgh, PA) configured to their physical characteristics using the SenseWear Professional software (v. 6.1.0.1528, 2007, BodyMedia Inc, Pittsburgh, PA) along with instructions for use of the armband.

**BodyMedia SenseWear Armband**

The BodyMedia SenseWear Pro3 armband used in this study is a 2.8 oz device worn on the right upper arm that gathers raw physiological data, including movement, heat flux, skin temperature, near body temperature, and galvanic skin response. This data allows for software analysis of total energy expenditure (kcal/min), active energy expenditure (kcal/min), METs, total number of steps, physical activity levels and duration, sleep duration and efficiency, lying down time, and on/off body time.

Previous studies supported the validity of measuring free-living activity with accelerometers similar to the SWA in adolescents and adults (25-29). Studies investigating the accuracy of accelerometer-derived measurements of exercise found accelerometers to be accurate in measuring energy expenditure for light and moderate to vigorous exercise intensity compared with indirect calorimetry and doubly labeled water (25,30-33). However, previous studies that utilized the SWA found that some forms of exercise, including in-line skating and stationary cycling, were not measured accurately by the SWA (34,35). Additionally, two studies involving endurance athletes found that the SWA underestimates energy expenditure at higher energy expenditure levels with a threshold for accuracy at approximately 10 METs (33,36). However, because the current study looked at MET categories rather than total energy expenditure, this issue with the SWA was minimized. Matthews, Ainsworth, Thompson, and Basset as well as Scheers, Philippaerts, and Lefevre investigated the amount of wear time needed for accurate assessment of physical activity levels by accelerometer and found that seven days of monitoring allowed for reliable measurement of activity with acceptable subject compliance, which decreased with longer wear time (37,38).

**MET Categories**

MET categories were established for the study prior to collecting data based on the MET categories set by the PAGA and the accepted MET range characterizing sedentary behavior (1,17). The PAGA has defined three MET categories: light-intensity, moderate-intensity, and vigorous-intensity. The corresponding MET values for these three categories are 1.1 to 2.9 METs, 3.0 to 5.9 METs, and 6.0 or more METs, respectively. Pate, O’Neill, and Lobelo defined sedentary behavior as behavior with an energy cost of 1.0 to 1.5 METs, a definition that has been incorporated into other recent studies of sedentary behavior (1,2,12). The SWA measures sleep time and in this study, sleep was treated as distinct from sedentary behavior since adequate sleep is considered to have positive health benefits not associated with sedentary behavior (39-41). Thus, for the purpose of this study 1.0 through 1.5 METs, not including sleep time measured by the SWA, served as the definition for sedentary behavior and the PAGA guidelines were used for the other categories, with light-intensity activity overlapping with sedentary behavior (Table 1).
TABLE 1. MET Categories Used in Current Study Compared to 2008 Physical Activity Guidelines for Americans (PAGA) MET Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Current Study</th>
<th>PAGA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
<td>1.0-1.5 METs (sleep excluded)</td>
<td>N/A</td>
</tr>
<tr>
<td>Light</td>
<td>Up to 2.9 METs (includes Sedentary)</td>
<td>1.1 to 2.9 METs</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.0 to 5.9 METs</td>
<td>3.0 to 5.9 METs</td>
</tr>
<tr>
<td>Vigorous</td>
<td>6.0 and greater METs</td>
<td>6.0 and greater METs</td>
</tr>
</tbody>
</table>

**Experimental Procedure**

Between February 2012 and April 2012, data was collected from seven groups of six to eight subjects. The groups were balanced such that the number of subjects from each group and each gender was similar to control for differences in weather, academic schedule, etc. Data was not collected during weeks with an atypical schedule including spring break and Easter break. Subjects were expected to wear the SWA continuously for 168 hours (the equivalent of seven days) subsequent to activating the armband on their body with the exception of time for personal hygiene. In the case of activities requiring removal of the SWA other than hygiene, subjects were asked to record the time, duration, and nature of the activity. Subjects left the preliminary meeting wearing the armband and were asked to return the armband at approximately the same time the next week. The target for wear time was at least 95% of minutes for the week. Subjects returned the armband along with a record of any activities other than showering/hygiene during which the armband was not worn. MET values from the compendium of physical activities for self-reported activities during non-wear time allowed estimation of MET totals equivalent to 95% wear time for subjects who did not achieve the target (42). Non-wear time by subjects achieving the 95% wear time target was deemed non-contributory to sedentary time based on subject self-report and was reported as “non-wear time”. All participants received a document containing a summary of their personal activity for the week.

**Statistical Analysis**

Prior data about time spent in sedentary behavior in adults appropriate for calculating needed sample size was not available. Therefore, sample size was based on detecting a mean difference in average daily METs of 15% with an α of 0.05 and a β of 0.10 using data from a study evaluating the energy expenditure patterns of normal weight and obese adults (43).

The difference in mean sedentary time between the CDR and RAS was analyzed with VassarStats (VassarStats, www.vassarstats.net, ©Richard Lowry, 1998-2012) using 2x2 factorial ANOVA for independent samples with standard weighted-means analysis. Statistical significance was set at $P < 0.05$.

**Results**

**Participants**

Forty-eight total subjects participated in the study. Twenty-two subjects in the CDR participated with 12 females and 10 males in this group. All CDR were NCAA DIII distance runners competing in races from 800m to 10000m. Twenty-six subjects in the RAS group participated with 12 females and 14 males in this group. CDR and RAS participants did not differ with regard to age (Table 2). With regard to height, weight, and body mass index, there
Comparison of Sedentary Time

was significant difference ($P < 0.05$) between the mean for CDR and RAS as well as between the mean for men and women (Table 2). Male CDR had significantly lower body fat percentage ($P < 0.01$) than male RAS and female CDR had a significantly lower body fat percentage ($P < 0.05$) than female RAS (Table 2).

### TABLE 2. Participants’ Demographic and Anthropometric Characteristics (n = 48).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Competitive Distance Runners (n = 22)</th>
<th>Recreationally Active Students (n = 26)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female (n = 12)</td>
<td>Male (n = 10)</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>20.7±1.2</td>
<td>21.1±1.6</td>
</tr>
<tr>
<td>Height (in)*</td>
<td>64.2±2.2</td>
<td>70.2±2.6</td>
</tr>
<tr>
<td>Weight (lbs)*</td>
<td>123.1±13.8</td>
<td>150.9±12.1</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)*</td>
<td>20.9±1.5</td>
<td>21.5±1.3</td>
</tr>
<tr>
<td>% Body Fat**</td>
<td>17.7±2.6</td>
<td>6.3±2.2</td>
</tr>
</tbody>
</table>

Values are mean±standard deviation

* Significant difference between the average for men and the average for women ($P < 0.05$) and significant difference between the average for competitive distance runners and the average for recreationally active students ($P < 0.05$)

** Significant difference between the average for male competitive distance runners and the average for male recreationally active students ($P < 0.01$) and significant difference between the average for female competitive distance runners and female recreationally active students ($P < 0.05$)

**Subject Compliance with Wear Time**

Forty-six of 48 subjects met the pre-determined target wear time of 95% for the week. Two female CDR achieved 87% and 88.7% wear time but the missed wear time was corrected according to the procedure described in the methods section.

**Sedentary Time**

No significant difference in sedentary time was found between the groups. The mean time

![Figure 1. Sedentary Time in Minutes/Week Compared between Male NCAA DIII Distance Runners, Male Recreationally Active Students, Female NCAA DIII Distance Runners, and Female Recreationally Active Students.](image-url)
Comparison of Sedentary Time

plus standard deviation spent sedentary by male CDR was 4326.4 ± 562.8 minutes per week or 618.06 ± 80.4 minutes per day; female CDR were sedentary 4373.9 ± 445.0 minutes per week or 623.7 ± 73.7 minutes per day (Figure 1). Male RAS were sedentary 4494.6 ± 662.0 minutes per week or 642.1 ± 94.6 minutes per day; female RAS were sedentary 4357.9 ± 598.8 minutes per week or 622.6 ± 85.5 minutes per day (Figure 1).

**Vigorous Physical Activity Time**

Although sedentary time between the groups was not significantly different, differences in overall quantity of physical activity were apparent in some groups and most of this variation had its origin in vigorous activity time. Male CDR spent significantly greater time in the vigorous physical activity category at 485.3 ± 121.3 minutes per week (69.3 ± 17.3 minutes per day) compared to male RAS ($P < 0.01$) at 178.1 ± 98.1 minutes per week (25.4 ± 14.0 minutes per day) and female RAS ($P < 0.05$) but not female CDR (Figure 2). Female CDR spent significantly greater time in the vigorous physical activity category 341.8 ± 83.0 minutes per week (48.8 ± 11.8 minutes per day) than male RAS ($P < 0.05$) but not than female RAS at 229.1 ± 234.6 minutes per week (32.7 ± 33.5 minutes per day) or than male CDR (Figure 2). This resulted in a significantly higher value ($P < 0.05$) for average METs for the CDR at 2.0 ± 0.22 METs than the RAS at 1.8 ± 0.28 METs.

![FIGURE 2. Comparison of Minutes per Week in the Vigorous Activity Category between Male Competitive Distance Runners, Male Recreationally Active Students, Female Competitive Distance Runners, and Female Recreationally Active Students.](image)

**Discussion**

The aim of this study was to determine whether NCAA DIII distance runners compensate for the time and energy required by their training by accumulating more minutes at a sedentary activity level than recreationally active college students with the hypothesis that subjects in the CDR group would spend more time in the sedentary MET range. Given that there was no significant difference between sedentary time in the CDR and RAS group, participation in NCAA DIII distance running does not seem to increase propensity for sedentary behavior
Comparison of Sedentary Time

Compared to students who are recreationally active, CDR spent more time engaged in vigorous activity resulting in greater average METs for the CDR, suggesting that collegiate distance runners are more physically active because the intensity of their exercise is greater than that of RAS, not because they spend less time engaged in sedentary behavior.

Findings of previous research on energy conservation in amenorrheic female distance runners suggesting that these individuals may engage in compensatory behavior to reduce energy expenditure apart from training activity did not correspond to the findings of the current study, which found no greater sedentary behavior in distance runners compared to individuals participating in less intense physical activity (22-24). However, the current study did not examine the energy intake of participants and therefore could not examine the relationship between restrictive energy intake and energy expenditure as in the studies with amenorrheic distance runners. This study was the first to directly investigate sedentary behavior in college athletes and recreationally active college students, preventing comparisons with previous data on sedentary behavior in these groups. Furthermore, previous studies of sedentary behavior in other populations have not utilized established guidelines for quantifying sedentary behavior and have used a variety of methods, including phone surveys and self-report, as well as different units of measure that have limited quantification of sedentary behavior (12). Lack of data in the area of sedentary behavior inhibited comparisons of findings from the current study to previous research. However, comparisons with a few relevant studies were made to provide some context for the findings of the current study.

In studies of physical activity in college students by Dinger and Behrens, Raynor and Jankowiak, and Matthews et al., activity was categorized by number of accelerometer activity counts per minute, with 0-499 counts representing the inactive category (21,37,44). The inactive time observed by Dinger and Behrens, Raynor and Jankowiak, and Matthews et al. for men was 793 ± 72.7, 1262.4 ± 42.8, and 739.8 ± 76.6 minutes per day, respectively. For women, inactive time was 778.6 ± 84.8, 1258.5 ± 45.0, and 747.9 ± 66.0 minutes per day, respectively. In the current study, male and female college students spent 632.1 ± 17.9 minutes per day and 623.7 ± 15.0 minutes per day, respectively, in the 1.0-1.5 METs category. However, the 0-499 counts category may not correspond directly with the sedentary category of 1.0-1.5 METs used in the current study because equations for converting counts into MET values vary widely (45). Therefore, this only weakly suggests but does not confirm that the students in the current study spent less time in the sedentary MET range than students in the comparison studies. Other attempts to compare the sedentary time data from the current study to other studies encountered similar difficulties.

Comparing vigorous activity time to findings in other studies was less problematic because the 6.0 MET threshold for vigorous activity has been standardized by the PAGA and most studies have adhered to that standard when establishing cut points for vigorous activity (17). Raynor and Jankowiak observed 6.9 ± 8.6 and 4.1 ± 6.3 minutes per day of vigorous activity in male and female college students, respectively while Dinger and Behrens observed 5.4 ± 6.4 and 5.3 ± 7.1 minutes per day of vigorous activity in male and female students, respectively (21,44). Analysis of accelerometer data from the 2003-2004 NHANES by Troiano et al. suggested vigorous physical activity among the 16-19 year old males ranged (depending on race/ethnicity) from 2.6 to 4.1 minutes and from 0.6 to 2.3 minutes per day among 16-19 year old females (16). Both the CDR and RAS of both genders greatly exceeded these comparison values for vigorous-intensity physical activity. The CDR averaged 58.1 ± 17.7 minutes per day and the RAS averaged 28.8 ± 24.7 minutes per day. Thus, compared to groups in similar age and...
lifestyle categories, both the CDR and RAS were more active. Since active subjects were purposefully recruited, this finding was expected.

A significant limitation of the study was lack of analysis of how the subjects accrued their physical activity and sedentary time. Other studies of physical activity and sedentary behavior analyzed physical activity and sedentary time by only counting sessions or “bouts” of activity/sedentary time that were at least 10 minutes in duration. Because physical activity guidelines, including the PAGA, recommend accumulation of activity via bouts of at least 10 continuous minutes to achieve the claimed health benefits, analysis of physical activity bouts may more accurately reflect the amount of physical activity with significant health benefits performed by subjects (16-18,21). Similarly, because long, uninterrupted periods of sedentary behavior are considered more of a risk than sedentary periods frequently interrupted by light activity, considering breaks in sedentary time as well as total sedentary time could provide distinguishing details about subjects’ activity profiles (46-51). Overall, assessment of bouts of activity and sedentary time might have revealed differences in the way sedentary time was accrued by CDR and RAS.

The interindividual variability of METs may have impacted the accuracy of the results. The value of one MET was derived from a 70 kg, 40 year old male and several studies have suggested that the assumed value of one MET overestimates the resting metabolic rate of individuals with characteristics differing from the standard (52). Since the subjects in the current study varied widely in terms of height and weight and included men and women, the assumed value of one MET may have been inaccurate for some participants. This potential effect might have been compounded by inaccuracy of the SWA for certain activities, including exercise at intensities above 10 METs and stationary bicycling (33-36). However, this limitation was controlled by using MET categories with a range. Any activity with an energy cost of 6.0 METs and above was considered vigorous, so inaccuracy above 10 METs would not have changed minutes in the vigorous category. Selection subjects who mainly ran/walked for physical activity limited the effect of inaccurate measurement of certain alternate activities.

Another limitation to consider is the small population for subject selection, which limits the applicability of this study. Only CDR from the Messiah College track team were recruited and because each track program has different schedules and training protocols, inclusion of collegiate distance runners from other NCAA DIII schools would enhance the applicability of the study.

Conclusion

Participation in NCAA DIII distance running was not found to lead to greater sedentary time compared to a recreationally active pattern. Overall, both groups were more active than the general population but male collegiate distance runners were most active due to greater intensity of activity. Additional research is needed to establish guidelines for sedentary time.

Recommendations for future research include establishing guidelines for sedentary behavior so that comparison of data across different studies becomes more practicable, gathering data about interruptions in sedentary time when investing spent sedentary, and exploring sedentary behavior in athletes from other sports.
References


